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CURRENT DEVELOPMENTS
LIGHTER THAN AIR SYSTEMS

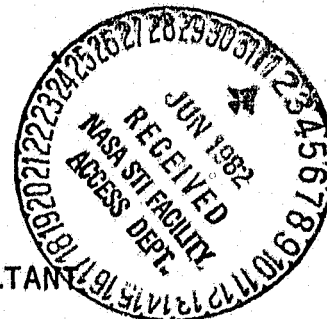
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
CONFERENCE ON LTA SYSTEMS TECHNOLOGY FOR
THE BENEFIT OF DEVELOPING COUNTRIES

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Abstract

Lighter-than-air aircraft (LTA) developments and research in the United States and other countries are reviewed. The emphasis in the U.S. is on VTOL airships capable of heavy lift, and on long endurance types for coastal maritime patrol. Design concepts include hybrids which combine heavier-than-air and LTA components and characteristics. Research programs are concentrated on aerodynamics, flight dynamics, and control of hybrid types.

Introduction

In the interval between the termination of U.S. Navy airship operations in 1962, to about the middle of the 1970 decade, the field of lighter-than-air aircraft (LTA) engineering and development was in a dormant state. The only continuity during that period was provided by flight operations with modified World War II type training airships by private firms in the U.S. and West Germany.

A renaissance of sorts is now occurring in which there is world-wide interest in LTA, evidenced by several government and privately sponsored studies and some actual aircraft development. Several stimuli have served to create this new attention to an old subject. Perhaps the most important is the potential for new transport capability in a world of changing requirements. These have emanated from the increasing demands for heavy-lift caused by development of energy related resources in remote areas, harvesting of timber from relatively inaccessible locations, and by growth associated with industrial development.

A second stimulus is the need for greater transport efficiency through elimination of inter-modal operations, reduced terminal time, and higher fuel economy. Such demands in the past led to the development of containerized cargoes and new surface ship development - pointing the way to aerial systems to handle larger sized payloads.

Transportation in nations of the third world constitutes a great potential for advanced aircraft development which could provide capability to bypass some of the evolutionary development of surface infrastructure which is often non-existent and difficult and expensive to develop.

A further incentive is produced by the increased awareness of all nations to conserve marine resources with the consequent establishment of extensive off-shore zones of protection which require new surveillance capability.

These new applications have created requirements for airships with characteristics considerably changed as compared to past designs. These include VTOL capability under a variety of conditions, long period hovering, and in some cases higher speeds. Such capabilities may not be available without the combining of LTA and HTA (heavier-than-air aircraft) features. These hybrid concepts will require the development of basic aerodynamic data, better understanding of their flight dynamics, and other new technology.

In the following descriptions of current developments, the various aspects of this relationship between new technology and aircraft development will be emphasized. In this review, various airship types will be described using an established method of referring to their structural systems. This method has been used with classical airships, as shown on the left side of Figure 1, but it can also be applied to the newer configurations shown on the right.

Current Developments

Aircraft Developments

United States - Two major programs, focused on different objectives are currently underway. One is the development of heavy-lift hybrid airships and the other is the evaluation of airships for maritime surveillance.

Interest in the heavy-lift application was generated around a concept by Frank Piasecki of the Piasecki Aircraft Corp. for combining helicopters and aerostat

TYPES OF LIGHTER-THAN-AIR AIRCRAFT

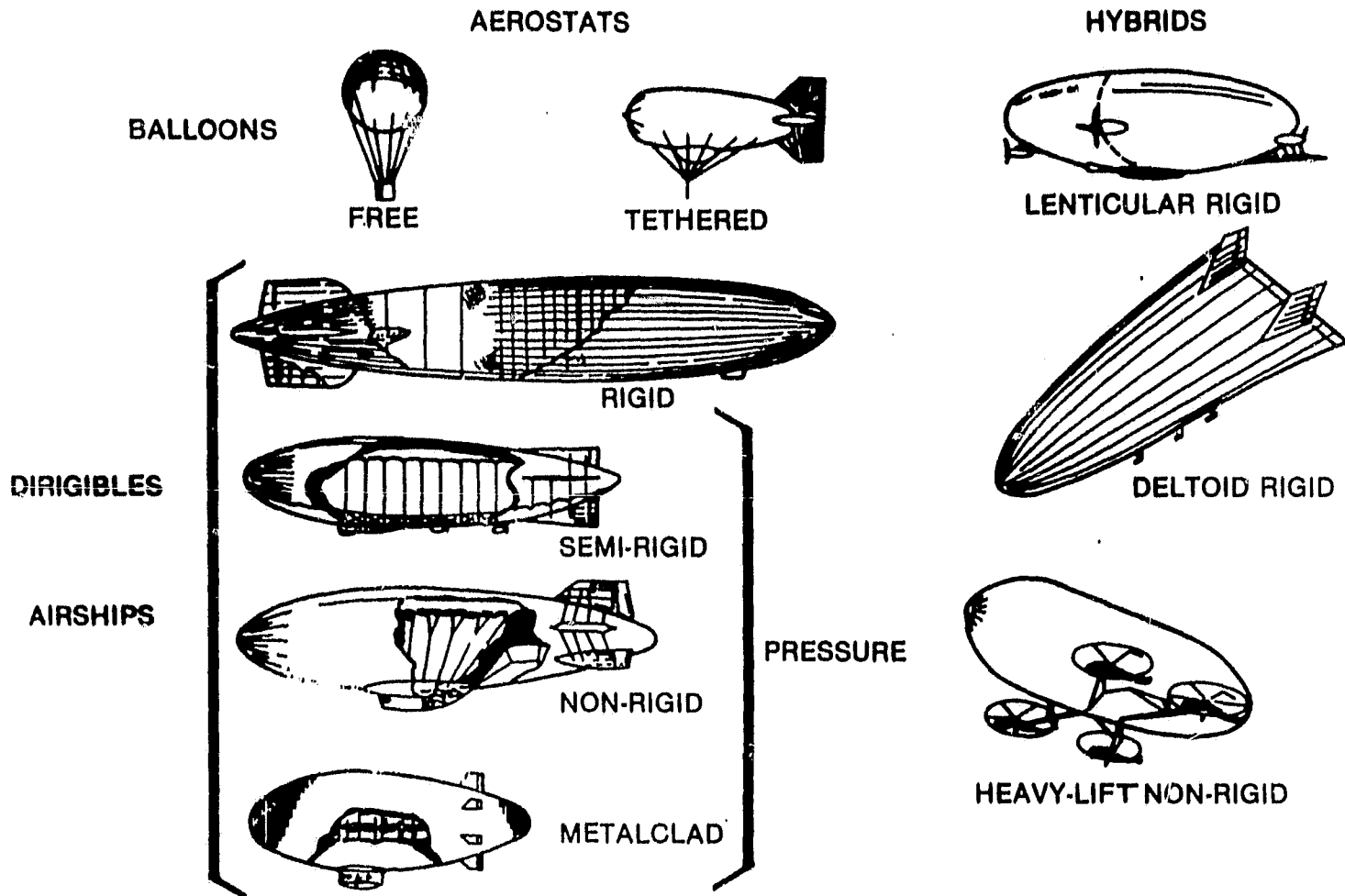


Fig. 1

hulls to obtain large vertical lift capability beyond present helicopter capacities up to an order of magnitude increase. This concept appeared to be a fortuitous solution to a current military problem of off-loading cargo vessels in ports where facilities do not exist or have been destroyed. Various hybrid types and combinations were studied by the Goodyear Aerospace Corp. under NASA sponsorship (Ref. 1) (and later independently). The most recent proposed Goodyear configuration includes rotors and drive components modified from current helicopters, forward and reverse propellers for horizontal propulsion and a 75050 m³ envelope with a payload of 68 tonnes. (Fig. 2)

Although an operational requirement was written by the Navy for a heavy-lift hybrid (Ref. 2), no program for development was authorized. NASA has continued to explore the dynamics and control characteristics of the concept however, (described under technology development), and a study was sponsored to explore the potential market for the type which included several concepts and configurations (Ref. 3). This study indicated that a substantial number of applications do exist for heavy vertical lift vehicles of various sizes. These results are summarized in Table 1. It can be seen that a leading application is in aerial logging.

The Piasecki Corp. has also continued to study various combinations of helicopters and aerostats and has participated in several NASA and Navy sponsored studies to evaluate various aspects of the concept. In 1980, the U.S. Forest Service awarded a contract, to be administered by the Navy, to Piasecki for the development and operation of a Heli-stat for a demonstration of aerial logging of Federal forests in the U.S. Northwest. This vehicle is shown in Fig. 3. It will utilize a large number of components from Navy spare aircraft. The major components are four H-34 helicopters and a 27613 m³ ZPG-2 Navy airship envelope. The helicopters will be modified to accommodate forward and reverse thrust propellers. This hybrid will lift a nominal 25 tons of payload. It is being constructed at the Naval Air Engineering Center at Lakehurst, N.J., and is scheduled for delivery in May, 1982.

Since 1976, the U.S. Coast Guard has been engaged in an investigation of various methods of implementing their requirements and responsibilities resulting from the Fishery Conservation and Management Act which established a 200 mile zone outward from most U.S. coasts covering an area of 2.2 million square miles. Added to these needs were problems caused by illegal maritime traffic. The U.S. Navy has been assisting in studies of a number of types and sizes of airships which might be suitable for Coast Guard missions (Ref. 4). These studies indicated that airships

could be compatible with Coast Guard operations and would show improved capability over certain air and surface units now in use. A comparative plot is shown in Fig. 4. For the cases selected, it was determined that airships could complete from 80-100 percent of the missions at costs equal to the HC-130 airplane and at 50-60 percent of the cost of ship operations. In 1980, NASA entered into a joint agreement with the Coast Guard to also assist in the assessment of airships and to develop necessary related technology. Current R&D plans call for the procurement and operation of an airship to engage in various Coast Guard missions. The extent of mission operation would be limited by the size and performance of the airship which in all likelihood will be of smaller scale than one required for full mission operation. The flight program would include both operations with and independent from surface craft to demonstrate hovering, detection and surveillance, air-sea rescue and other missions. This program will be conducted by the Navy.

A few private efforts involving airship development also exist in addition to government sponsored programs. One of these, by D.C. Associates in Delaware, is described under Canadian programs.

Canada - Several events in Canada have resulted from recent growth and development of the Northwest territories and some of the Western provinces. Studies sponsored by the Ministry of Transportation identified several types of modern airships which might be suitable for transport systems in this area (Ref. 5). Economic analyses in this study indicated that enormous savings in transport expense were possible through the use of some kind of heavy-lift VTOL aircraft. These savings would accrue from the elimination of road construction - and reconstruction due to weather effects, elimination of time delay by by-passing obstructions (rivers, canyons) direct delivery of men and equipment, and extension of the working season.

The logging of timber in these Northwestern regions is also an attractive use of heavy-lift hybrid airships. One type being developed for such use is the Cyclo-crane, a patented concept of D.C. Associates. This vehicle is a unique combination of rotorcraft and aerostat. It consists of an ellipsoidal non-rigid aerostat hull supporting 4 rotor wings radially from points along its maximum diameter. The wings are equipped with tip airfoils and propellers. The entire hull and wing system rotate, driven by the propellers such that control and propulsion forces are developed by wing system regardless of forward speed. A 1.8 tonne 9487 m³ demonstration model is being purchased by Canadian Forest Products Industries, a private group. It will be tested in Tillamook, Oregon and later operated in



Fig. 2.

Production Configuration -
Heavy-Lift Airship

WORLD MARKETS FOR HEAVY-LIFT AIRSHIPS

APPLICATION	NUMBER OF AIRSHIPS*					
	PAYLOAD	30	75	150	300	800
LOGGING		1082	600			
MARITIME LOGISTICS		27	10			
PETROLEUM DRILLING & TRANSPORT		3	4			
POWER PLANT & POWER LINE CONSTRUCTION		9		1	5	1
TRANSPORTATION						4
TOTAL		1121	614	1	5	5

*ASSUMES 2000 HR/YR UTILIZATION

Table 1.

HELISTAT GENERAL ARRANGEMENT

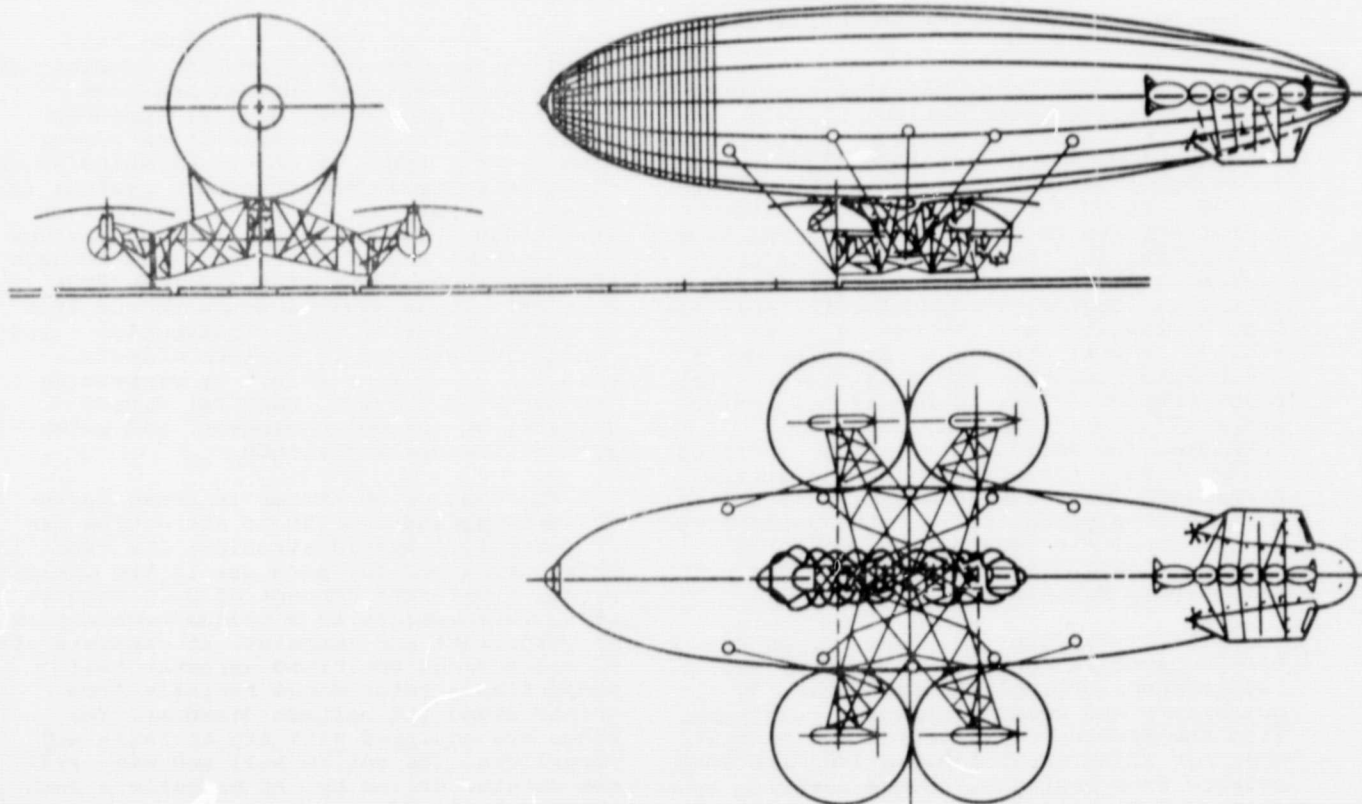


Fig. 3.

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the Canadian province of Vancouver. Flights will begin in the summer of 1981. A scale model used for research is shown in Fig. 5. Continued interest exists in Canada to sponsor home industries needed to implement development of resources, etc. This could lead to the establishment of companies in Canada to build and operate airships.

Great Britain - Interest in LTA in Great Britain has never ceased, although Government sponsorship of any work has. As a consequence, limited private interests have been confined largely to studies of various concepts or to small experimental airship projects. In recent years, one firm, Aerospace Developments (later called Airship Developments), combined their own design engineering capabilities with those available from specialized contractors to produce a small non-rigid with several advanced features, designated the AD-500 (Fig. 6). All components were fabricated by separate manufacturers in England, France, and Germany, with final assembly of the airship provided by Aerospace Developments. This airship was wrecked following its second flight during ground handling.

Another organization, Skyships, later known as Thermo-Skyships experimented with lenticular shaped vehicles in scale model form. Recently Thermo-Skyships and Airship Developments merged to form Airship Industries, Ltd. Their plans include two major objectives. The prime one is in the building of several sizes of non-rigid airships beginning with an improved version of the AD-500 now known as Skyship 500. This 5132 m³ airship will include a re-designed control system, mooring system, and envelope. The control system will employ optical fibers to transmit control signals to actuators located at the control surfaces. The mooring system has been strengthened to withstand higher forces, and the envelope is designed for improved gas retention. The new 500 is scheduled to make its first flight during the summer of 1981.

A stretched version of the 500 is also under development. This is designated Skyship 600. It will contain a 6 meter parallel middle body providing an additional 0.9 tonne of lift. The car will also be stretched 2.5 meters and will be equipped with 2 supercharged Porsche 250 H.P. engines driving two tilting ducted fans (as in the 500). This power will allow a top speed of 65 knots with a vertical lift-off capability up to 500 kg.

The company is also contemplating a larger non-rigid, designated Skyship 5,000 of 42480 m³ envelope volume.

Another, somewhat separate objective is in the design and construction of large metalclad airships (approx. 127400 m³ ft.) to be used as freight transports for

both short and long range operation. Two major stockholders in the company are freight transport companies and they are interested in the potential which such airships offer for fast lower cost service. Much of this economy is expected to result from use of natural gas as a primary fuel. Studies are continuing on this concept and no specific design as yet has evolved. It is anticipated that the final design will have an ellipsoidal hull shape rather than lenticular as originally planned although some model testing continues on the latter type as well.

Airship Industries has tentative orders for 500 and 600 series airships for training, patrol, and advertising, and interest is being shown in the larger non-rigid and rigid type as freight transports.

West Germany - As in Great Britain, activities in Germany are privately sponsored. The most active company, West Deutsche Lufterwerbung GmbH (WDL), has been operating two non-rigid airships in Germany and Japan for aerial advertising. These aircraft are modified versions of Goodyear "L" types, the design of which predates WWII. However, several new features have been incorporated in the WDL modifications. These include fuel tanks suspended by the internal car suspension cables within a center ballonet, improved air pressure systems, slightly larger envelopes (6,000 m³), and tractor propellers. As of March, 1981, the two airships were being overhauled and scheduled to commence flight operations in April and May.

WDL has also completed a preliminary design study of a larger non-rigid, the WDL III (60,000 m³), which would feature diesel engines located within the envelope, vectoring turbines for maneuvering control, and removable cargo and passenger modules. Specific development plans have not been made for this airship.

The name of Luftschiffbau Zeppelin has been restored as an active part of Zeppelin Metalwerke, GmbH in order to respond to the continuing interest for historical materials and information, and to remain current on new developments. No plans have been announced to resume airship construction activities, however.

France - Various government and private organizations in France have sponsored studies of airship applications and airship concepts. Two agencies in particular, ONERA and SNIAS have investigated hybrid aircraft some of which are similar to concepts proposed in the U.S. involving helicopter-aerostat combinations. One of these, called the HELICOSTAT, featured a tri-lobed non-rigid envelope and 2 Turbomeca Arriel turbines driving AS350 Ecureuil rotors to provide forward and reverse thrust. If the aircraft had been built it was to have been used to demonstrate aerial logging,

EFFECTIVENESS OF AIRSHIPS
COMPARED WITH OTHER COAST GUARD CRAFT

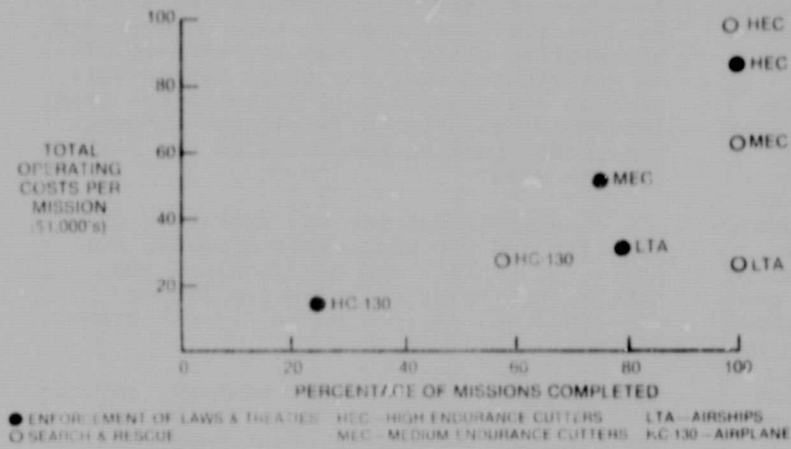


Fig. 4.



Fig. 5.

CYCLOCRANE Flying Model

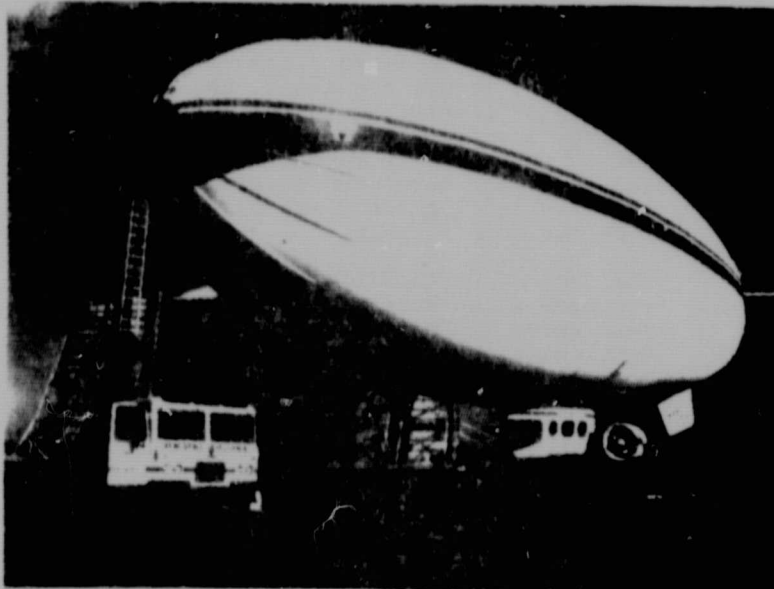


Fig. 6.
AD-500 Airship

however, no construction is planned at present. (Ref. 6)

The same envelope concept was used in an experimental RPV designated DINOSAURE. In this 40 cubic meter mini-airship, 2 envelopes were joined to form a lifting body shape. Other features included blown controls and an air cushion landing system. The model shown in Fig. 7 was used for atmospheric research and completed 70 flights (Ref. 6).

A French engineer, M. Balascovic, has been experimenting with lenticular shaped hulls and has proposed several versions named Pegase, Titan, and Vespa. A single place flight vehicle, "Flipper", was constructed in 1978 to provide early data. (Ref. 6) Unfortunately, the aircraft was damaged beyond repair prior to its first flight. Present plans by Balascovic and his company S.E.A.B. include development of a 6,200 cubic meter airship called ALCYON. A model of this aircraft is shown in Fig. 8. It is intended as a low altitude VTOL vehicle. Vertical thrust is obtained from 3 rotor systems located at 120° points on the hull perimeter. Forward thrust is provided by 3 propulsive units mounted on the tail support structure of the aircraft. Although the vehicle has a large horizontal tail, it was judged to be inherently stable (in pitch) without this appendage on the basis an analysis provided by CERT (the Toulouse branch of ONERA). Wind tunnel tests to measure drag were also run by ONERA. A full scale vehicle is planned for completion in 1982.

Japan - The Japanese Ministry of International Trade and Industry (MITI) has sponsored studies to identify missions in which modern airships may be useful. Many of these included the transport of electric power generating equipment to various relatively inaccessible locations in the Japanese Islands. Others included supplying populations located on the many small islands of the Japanese nation. Favorable results were shown in terms of the indirect costs which would be eliminated through the use of airships such as road construction, airport runways, bridges, etc. The studies also identified a heavy-lift type of hybrid carrying between 20-100 tonnes of payload. Following the study, a program of development was recommended, but it has not been implemented to date. (Ref. 7)

South America - There has been sporadic interest on the part of several countries in South America. The most serious effort was undertaken by a Venezuelan firm in financing the development of the Aerospace Developments Ltd. AD500 airship in the U.K. as a public relations and advertising project. The late completion and later accident of the airship forced discontinuation of this connection.

The government of Brazil has conducted

studies involving dirigible transport but no results have been reported.

Several South American nations have similar problems regarding development and transport. These involve resources in remote areas requiring the transport of heavy equipment and limited by effects of seasonal weather. In a way, these are similar to some of the Canadian Northwest problems of development where terrain is not hospitable to road or rail construction and working periods are limited by accessibility. All of these tend to establish requirements for an aircraft capable of heavy-lift, VTOL flight, and one requiring a minimum of ground facilities, such as the heavy-lift hybrids.

Africa - A limited demonstration of airship operations was carried out by the German firm, WDL, under government sponsorship, in Ghana and Upper Volta, using a WDL-I non-rigid. The airship was shipped to Ghana and erected (in the open) at the airport. Conclusions on the results of these experiments were not publicized. It is understood, however, that interest in developing an air transport system suitable to the requirements of terrain and developments is continuing in several W. African nations.

II - Technology Developments

Configurations - In several countries, departures from the normal hull forms of ellipsoids and cylinders continue to be studied. These concepts have been considered for a number of reasons such as a desire for increased dynamic lift in flight, reduced resistance to ground winds while moored, or the need for a special hull form because of payload or mission requirements. Configurations include delta planforms, lenticular shapes, and ellipsoidal cross sections.

Objective evaluations of these concepts in comparison with conventional types is difficult because of the lack of an adequate data base (for the new concepts) and also because requirements for each type may not allow direct comparisons. One such evaluation (Ref. 8) was made recently on the basis of specific productivity for deltoid hybrids and conventional equilibrium types. (Spec. Productivity = Productivity/Airframe Weight & Propulsive Weight). The results show that hull forms of very low aspect ratio (~ 0.5) have slightly higher values (of specific productivity) than conventional shapes. These hulls would actually combine ellipsoidal fore bodies with flattened (delta shaped) afterbodies. These results seem to have been confirmed in an independent study (Ref. 9) which compared very large VTOL hybrids and equilibrium types for military airlift missions involving very long range flight. Fig. 9 illustrates the results of these investigations.

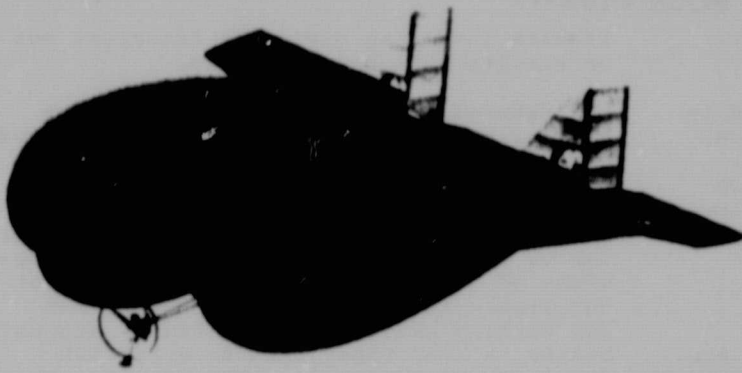


Fig. 7
DINOSAURE Mini RP7

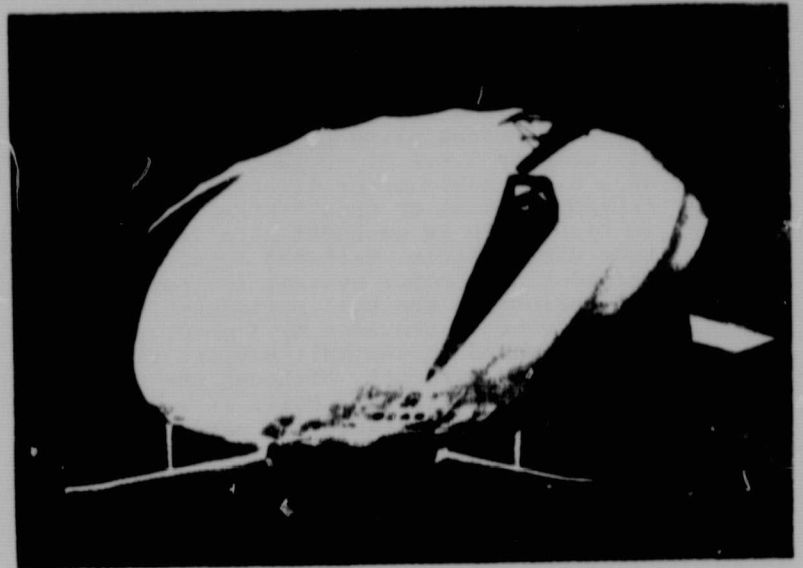


Fig. 8
ALCYON Model

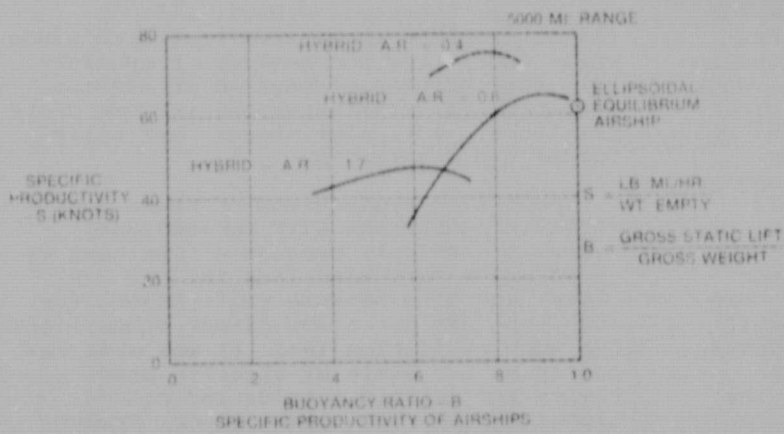


Fig. 9
Productivity Comparisons

It should be noted that the productivity values are low compared to airplanes at their best ranges, but possible features such as VTOL capability, large single payload and volume capacity, and the potential for extreme range flight could make some hybrids attractive for future development.

Dynamics and Control - Conventional equilibrium airships are usually designed to be controllable by aerodynamic means through the use of hull and empennage forces above some minimum flight speed. Below this point, static forces only are available for control. The new hybrid concepts which combine large rotors with aerostatic hulls are, by design, intended to circumvent this problem through the availability of large thrust forces at all airspeeds, and to achieve near helicopter-like hover capability. It also appears that some future airships will require rather precise controllability at or near zero airspeeds. These new flight characteristics will vary with mission applications but in general they establish needs for design criteria beyond the present data base. For this reason, the bulk of research effort in recent years has been devoted to the development of suitable analysis and simulation of flight.

One example of such effort is an analytical program developed by Goodyear (Ref. 10) for non-rigid heavy lift hybrids which models flight path simulation dynamic stability, and control concepts for various flight mission profiles. The vehicle motions, velocity changes, power requirements, fuel consumption, and suspended payload dynamics are recorded via strip charts and also displayed on CRT's.

A similar but more comprehensive investigation was initiated under NASA contract with Systems Technology, Inc. (Ref. 11). This program is intended to be developed in three sequences or versions. The first one incorporates the basic major elements of vehicle dynamics in steady flight with simplified rotor models. The second version contains the effects of hull-rotor interference, and atmospheric turbulence. Version three will include payload dynamic effects simulation, ground effects, and vehicle stability derivative determination. The complete analysis is scheduled to be completed in July 1981. It will be installed in NASA Ames computer equipment and also be available to other organizations with similar equipment. The various elements of this program will be adaptable for simulating a number of vehicle configurations including those with control and thrust units different in number and location from the basic heavy-lift form rotor concepts. The piloted simulator facilities at the NASA Ames Research Center are also being utilized to provide opportunities for piloted simulation of airship flight. This facility is shown in Fig.10.

Another approach to the study of flight characteristics is being employed by the Naval Air Development Center. This consists of a remote control flying model 9.75 m long and 24.5 m³ in volume. It will approximate a 1/10 scale version of a Coast Guard patrol vehicle concept, and will incorporate a tilting bi-rotor propulsion and control system.

Dynamics and control studies of conventional airships have also been conducted in Canada by DeLaurier (Ref. 12), and in France by ONERA, the French government aeronautical research agency. This latter work includes analysis of sling-load dynamics in connection with heavy-lift airship certification (Ref. 13).

A number of other analyses for specific concept developments have also been made in France, Great Britain, and the U.S.

A fundamental problem with most of these new programs is the lack of a suitable data base. Some of these new configurations have strained theoretical knowledge to limits without correlation with either wind tunnel or flight data. An early indication of some of these problems was revealed in discrepancies between small scale wind tunnel tests and analyses of hybrid concepts with large rotor systems (Ref. 14). Force vectors did not agree in magnitude or direction. Larger scale and higher Reynolds number tests are scheduled by NASA during 1982 to investigate these areas further.

Structures and Materials - Two developments in recent years which have major impact on airship structures are new methods of analysis, and new materials.

Past efforts in this area were extremely limited by the complexities of the structures. In rigid airships, for example, simplifications and approximations were required which only by experience provided reasonable results. In non-rigids, the envelopes and suspension system were treated by assuming that strength and elastic characteristics in major portions would exhibit relatively uniform behavior.

Finite element methods using digital computing equipment now provide a basis for more exact and more detailed computations. A particular advantage results from the ability to model (analytically) the dynamic behavior of systems taking into account nonlinear characteristics and coupling effects. Fig.11 illustrates the envelope and suspension system of a small non-rigid airship using a specifically developed program (Ref. 15).

Structural weight continues to be one of the most important elements in sizing airships, and hence determining their efficiencies. Weight reductions can be accomplished through the use of composite



Fig. 10.

Piloted Airship Simulation

**COMPUTER DRAWING OF NON-RIGID
AIRSHIP STRUCTURAL ELEMENTS**

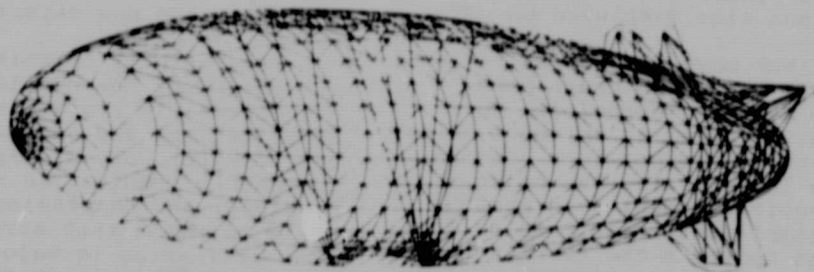


Fig. 11.

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ORIGINAL FIGURE OF POOR QUALITY

materials, and not synthetic filaments and films (for inflated components).

The envelope assembly is the largest single weight component in a non-rigid. A saving of half of this weight would result in a net reduction of 15 percent in envelope volume and 13 percent in propulsive power if a complete re-design is considered. Such savings may be possible using a combination of composites for the hard structural components with newer synthetic filaments such as Kevlar, and Graphite. An example of the actual application of new materials can be found in the British Airship Industries Skyship 500 which is described elsewhere in this paper. The ear, empannage, and nose mooring and stiffening components were built using combinations of Kevlar and fiberglass composites.

Another possibility for weight reduction in envelopes could result from a decrease in factors of safety. Currently, there is little or no research on the subject. Part of this determination needs to be based on better correlation between design criteria and actual service experience, similar to that reported in (Ref. 16) for Navy airships.

Some exploration of structural design criteria was undertaken as part of heavy lift hybrid airship studies sponsored by NASA (Ref. 1), but a considerable greater amount needs to be done if realistic requirements are to be established for new airship designs. Among these is the subject of gusts and turbulence. Criteria used for past airships may not be very applicable particularly for determining loads from maneuvering with much higher thrust and carrying suspended loads such as possible with some the heavy-lift hybrids.

Propulsion - It is not likely that engines specifically designed for airships will ever be available considering the small market such aircraft represent. In the past, engines designed for other uses have been adapted for airships using special gear boxes and components, and it is probable that future vehicle designers could be forced to continue this practice. A significant difference between the past and present, however, is the emphasis now on low speed control. This establishes requirements for higher thrust in some cases and for thrust vectoring through the use of tilting propellers and cyclic and collective pitch variation. With the exception of cyclic pitch, all of these systems have been incorporated in airships before but to a lesser degree.

Response time for counteracting disturbances is crucial if any thrust system is to be effective. Even though inertial characteristics of airships favor longer periods, these would be shorter than the time required for tilting thrust axes.

Thrust units already located in the proper direction seem to be one practical approach as was demonstrated by the side thruster shown on the model in Fig. 12. This experimental model, designated HX-1, incorporated tilting propellers and a tail thruster as well.

A French experiment, conducted by ONERA used two intermeshing propellers with axes at 90° to each other, demonstrated that both thrust and efficiency were enhanced as a result.

Operations - The actual operation of airships in the past 19 years has been limited to those involved with private U.S. public relations activities and German aerial advertising as previously noted. Both these groups have employed methods similar to each other and basically not different from previous naval operations. These include operations from a fixed base with hangar facilities and from portable equipment at various locations without hangaring. The German operation primarily has employed the latter method, with a hangar usually only available as an assembly facility.

An examination of the possibilities for ground handling heavy-lift hybrids was made by Goodyear and sponsored by NASA (Ref. 17). These indicated that nose mooring to a fixed or mobile mast continues to be the method by which weight penalties from structural loads on the airship are minimized. Fig. 13 shows the effects of total restraint (no weathervaning) on suspension system and envelope weight for a 68 tonne heavy lift airship of 75,100 m³ cu. ft. It can be seen that component weight could exceed total lift.

Certification - In the U.S., the only civil activity (Goodyear operations) is certified on the basis of similarity of the airships to Navy "L" type airships flown during WWII. For this reason, a detailed certification for airships of any type has never been developed. In contrast, the British Civil Aviation Authority was forced to develop a complete requirement (Ref. 18) during design and development of Airship Industries Skyship 500 - previously Aerospace Developments AD500. It is anticipated that a similar requirement will be developed by the FAA if new U.S. designs are built.

Comment and Summary

Table 5 is a list of the several LTA vehicles and their characteristics under development in various countries. The single largest project is the HELI-STAT program for the U.S. Forest Service. It is possible that the programs in the U.K., if successful, could surpass the investment levels now indicated for the U.S. projects. It is interesting to note that enterprises in the U.K. are privately supported even though the efforts involve



Fig. 12.
Vectored Thrust Test Model

EFFECT OF TOTAL RESTRAINT ON 75 TON HEAVY LIFT AIRSHIP

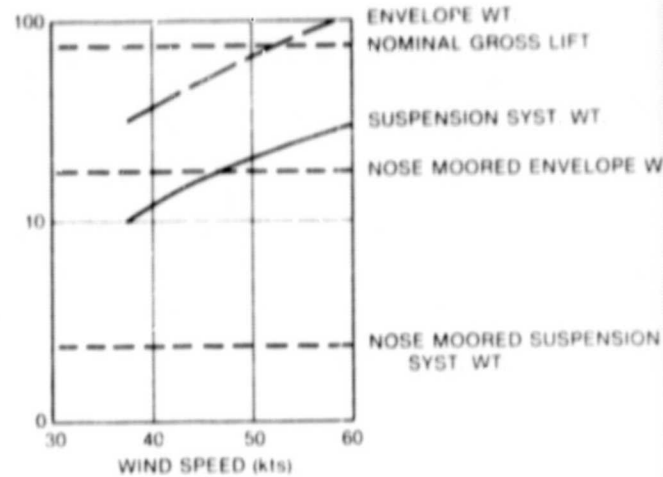


Fig.13.

CURRENT AIRSHIP DEVELOPMENTS CHARACTERISTICS

NAME/CO.	VOLUME m ³	LENGTH m	MAX. DIA m	GROSS WT. kg	GROSS LIFT kg	MAX. SPEED KNOTS	USEFUL LOAD kg	H.P.	COMMENT
HEAVY-LIFT AIRSHIP GOODYEAR	75050	138	33	131885	63858 ⁽¹⁾	80	68027	8760	UNDER STUDY
HELI-STAT PIASECKI	27613	105	23	5109	27021 ⁽²⁾	60-70	25569	5100	UNDER CONSTRUCTION
CYCLO CRANE D.C. ASSOC.	9487	55	20	10884	9070 ⁽²⁾	60	1814	360	UNDER CONSTRUCTION
SKYSHIP 500 AIRSHIP INDUS	5132	50	14	5703	5068 ⁽³⁾	62	1883	300	UNDER CONSTRUCTION
SKYSHIP 600 AIRSHIP INDUS	6055	56	14	6256	5707 ⁽³⁾	65	2883	500	UNDER CONSTRUCTION
WDL I W. DEUTSCHE LUFTWERBUNG	6000	60	15	6286	6286 ⁽⁴⁾	61	1497	500	UNDER CONSTRUCTION
WDL III W. DEUTSCHE LUFTWERBUNG	60000	122	30	62239	58716 ⁽²⁾	76	39909	2600	UNDER STUDY
HELI-COSTAT AEROSPATIALE	3400	37	15	6540	3447 ⁽²⁾	49	3447	1200	UNDER STUDY
DINOSAURE	47	8	1	46	46 ⁽⁴⁾	—	—	7	RPV OPERATIONAL
ALCYON	6200	44	9 ⁽⁵⁾	—	5687 ⁽²⁾	60	998	885	UNL R DEVELOPMENT
GZ 20A GOODYEAR	5741	59	14	5587	5587 ⁽²⁾	43	1488	420	OPERATIONAL

(1) @ 1524 m ALT.
(2) @ 305 m ALT.

(3) @ 610 m ALT.
(4) @ S.L.

(5) HEIGHT

Table 2.

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novel departures from past types. It is likewise noteworthy that the German operation which is devoted to advertising and which also involved some risk venture capitalization and is now reported to be self supporting. These operations should offer evidence that government support is not necessarily a prerequisite to the initiation of a new LTA venture.

The new types under study and development in most cases are a compromise between slow flying equilibrium airships with low energy consumption and faster more maneuverable concepts. But the total cost of flight vehicles is not fuel cost alone, although this factor will rise in importance as costs increase. As shown in the productivity studies of deltoid hybrids, such vehicles may be uniquely suited to certain mission applications provided that β^* values of 1.0 are not required. This is reasonable since no single type of vehicle of any kind has ever been found to satisfy all requirements.

LTA technology and development today appears to stand on the threshold of an era of new uses. Compared with other aeronautical types, these developments are miniscule and extremely vulnerable. Their viability is conditioned by the critical need for a true industrial base. None exists at present.

The particular design effort involved in the various projects described in this paper is somewhat akin to the kind of fragmented aeronautical endeavor that existed in the U.S. following World War I, where there was much enthusiasm, limited financing, and inadequate engineering in many cases.

Basic technology development should include all the subdisciplines involved in design, construction, and operation. It is generally true, however, that most research today is only in connection with particular concepts and only on subjects which appear to be obstacles to predictable design. Few if any of the incremental refinements normally associated with aeronautical research are part of current investigations. Whether these will be, remains to be seen. Without a continuing research effort there is little hope for true advancement in the field.

Among the many elements needing investigation, perhaps the most important are:

1. Large Reynold's number aerodynamic drag and the effects of various configuration changes.
2. Design and location of propulsion units for maximum efficiency.
3. Development of structural design criteria including particular definition of realistic requirements for flight in

turbulence and gusts for various airship concepts.

4. Envelope materials research to improve long term permeability, durability, and achieve lower weight fractions.

5. Improved methods of ground handling, maintenance, and determination of all-weather flight capabilities.

6. Realistic assessment of design, construction, and operational costs particularly related to specific missions and types.

The area of flight dynamics and control appears to be sufficiently emphasized in current programs and should continue to be an important aspect of future research as well.

In summary, current developments include continuing efforts in the U.S. in research on the dynamics and control of hybrid airships, structural analysis, and scaled experiments. Vehicle programs include the construction of a heavy-lift HELI-STAT for logging demonstrations and the building of a flight vehicle for Coast Guard mission demonstrations. Activities in foreign nations include building airships for demonstration of aerial advertising, passenger and freight transport, coastal surveillance, and general utility. The successful achievement of these and future efforts will be dependent on building an improved industrial base and broadened R&D effort.

* β = Static Lift/Gross Weight

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